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Study on Application Concept of Quenching Meshes for IRWST Hydrogen Control

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1. Introduction

According to the domestic and foreign regulations, a detonation or DDT (deflagration to detonation transition) should not be occurred in a containment [1,2,3]. A hydrogen control in the IRWST in severe accidents still remains as a debate issue to be solved in the APR-1400 [4,5]. It would be possible to occur DDT in the IRWST of the APR-1400 [6]. The objective of this paper is to show the performance of quenching meshes and to suggest conceptually how to prevent the detonation in the IRWST using quenching meshes.

2. Performance test of a quenching mesh

2.1.Test Facility

The test facility is consisted of the visualization system, the combustion chamber, the data acquisition system and the electric spark igniter system. It has been known that an initial pressure and flame speed affects the performance of quenching mesh. An initial pressure effect was tested in the combustion chamber of Fig. 1. The quenching mesh is located between the first and the second compartments. The flame speed effect was tested using the chamber of Fig. 2. The quenching mesh is located between the fifth compartment and the expansion vessel. The ignition node is installed at the end-center of the first compartment.

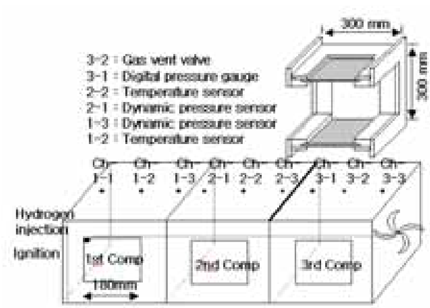

Fig. 1 Combustion Chamber

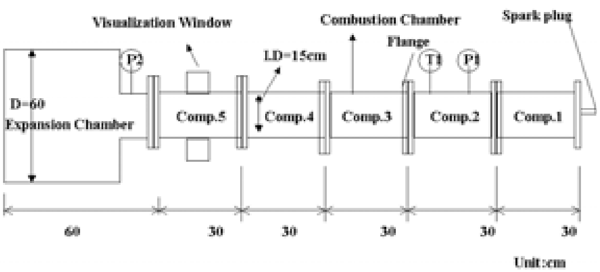

Fig. 2 Combustion chamber for a high flame speed

2.2.Test Results

An initial pressure in a containment in severe accidents is much less than 2.0 Bar before a hydrogen combustion in a containment occurs. Performance tests of quenching mesh were carried out from 1.0 to 2.0 Bar at 10% hydrogen mole percent with a dry air. Fig. 3 shows the temperatures at the front and back of mesh for 1.8 and 2.0 Bar. When the mesh was installed between compartments, the flame was quenched up to 1.8Bar, but it was not quenched at the mesh for 2.0Bar.

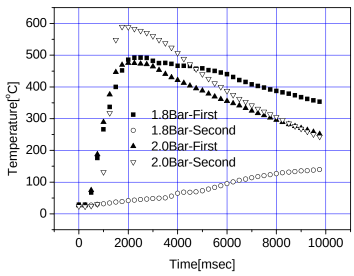

Fig. 3 Compartment gas temperature during burn

The flame speed effect was tested at an atmospheric pressure at around 9% hydrogen mole percent with a dry air. The moving flame with about 30m/s was not quenched when one sheet was used to arrest the flame. However, the flame was quenched when two sheets was used. Fig. 4 shows the pressure and temperature when two sheets were used.

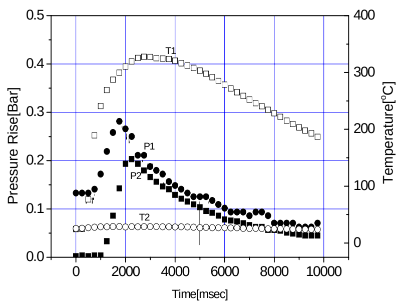

Fig. 4 Pressures and temperatures in the chamber

3. Application Concept of Quenching Mesh for IRWST Hydrogen Control

According to the current design of APR1400, there are two igniters and four passive automatic recombiners [PARs] in the IRWST. An ignition occurs by an igniter.

It is also proven to ignite by PARs if a hydrogen mole percent is greater than 9%. In other words, it can be said that ignition source always exists in the IRWST.

By the 3-D hydrogen analysis, the pressure in IRWST is less than 1.5 Bar. From the test results, the flame was quenched up to 1.8Bar. Meanwhile, it is important to estimate the flame speed in the IRWST because the mesh can play a quenching role only for a flame which is less than any flame speed. The quenching mesh should be installed before the flame accelerates. The flame speed depends on the geometric conditions of the combustion chamber and the flame path which is a distance from the ignition source. There are obstacles of PARs in the IRWST and four top openings. The effect of obstacles on the flame speed was investigated from previous research [7]. In a small-scale test with 3.5m in length and square tube of 0.268x 0.268m, it is found that low block ratio obstacles in the explosion tube do not severely accelerate the flame front to violent combustion modes.

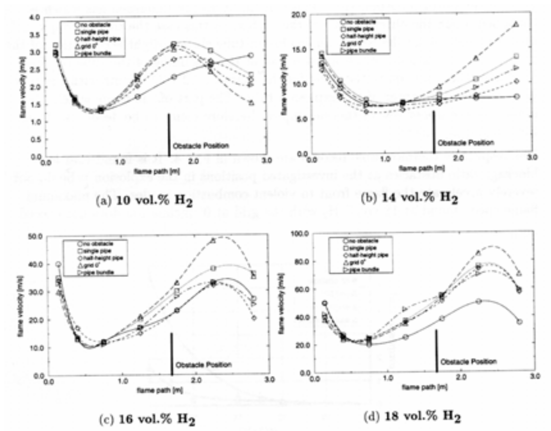

Fig. 5 Flame speed vs. flame path for obstacles[7]

Fig. 6 shows the flame speed when block ratio is 0.6[8]. The flame acceleration occurs above 5.0 of x/D except for the 25% hydrogen mole percent.

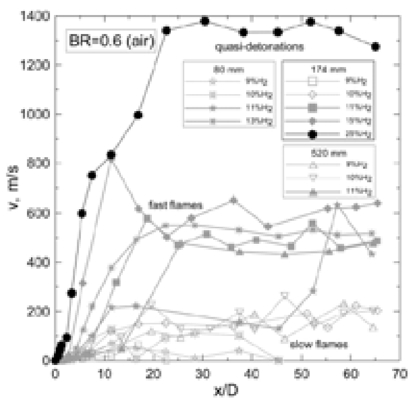

Fig. 6 Propagation speed of flames and detonation along the tube vs ratio of distance, x, tune diameter, D[8]

The top venting effect on the flame speed was investigated using the in a large scale test with 30m in length and square tube of 1.83x2.44m[9]. The flame speed was about 30m/s when hydrogen mole percent was less than 18%, as shown in Fig. 7. In this case, the flame is accelerated when x/D is higher than around 3.

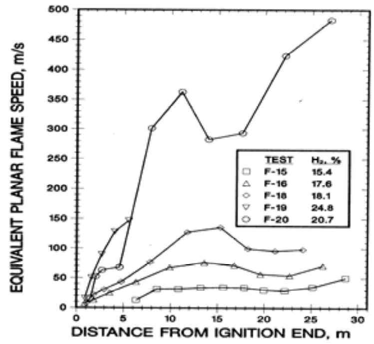

Fig. 7 Comparison of flame speeds for tests with 13% top venting and no obstacles[9]

The flame is not accelerated enough when x/D is less than 3 except for very high hydrogen mole percent over 20 %. For below 20 % hydrogen mole percent, it is expected that the quenching mesh of two sheets can play a flame quenching if it is installed within the 3 times of the length from the water level to the top of the IRWST from ignition source.

4. Conclusions and Recommendations

The possibility of the IRWST hydrogen control using the quenching meshes is suggested conceptually. The flame speed at the same geometry and top opening as IRWST is required to estimate the applicability of quenching mesh.

REFERENCES

[1] USNRC, 10CFR50.44, 2003.

[2] MOST, 과학기술부고시 제 2005-31 호, 2005.

[3] IAEA, Design of Reactor Containment Systems for Nuclear Power Plants, Sep. 2004.[4] KOPEC, KNGR Severe Accident Analysis Report, 1999.

[5] H. C. Kim, N.D. Suh, J. H. Park, Proc. of ICAPP05, Paper No. 5400, 2005.

[6] J. T. Kim, S. W. Hong, S. B. Kim, H. D.Kim, Hydrogen Mitigation Strategy of the APR1400 Nuclear Power Plant for a Hypothetical Station Blackout Accident, Vol. 150, No.3, pp. 263-282, 2005.

[7] AECL, Proc. of the OECD/NEA/CSNI Workshop ON the Implementation of Hydrogen Mitigation Techniques, pp. 433, 1997.

[8] S.B. Dorofeev, M.S.Kuznetson,V.I. Alekseev, A.A. Efimenko, W. Breitung, Evaluation of limits for effective accelerations in hydrogen mixtures, Journal of loss prevention in the process industries, Vol. 14, pp 583-589, 2001.

[9] M.P. Sherman, S. R. Tiszen, W. B. Benedick, Flame Facility, SNL, pp.107, 1989.